

- 1     1.     A method of forming a shell on a template, comprising:  
2           immersing the template in a slurry, the slurry comprising  
3           a plurality of colloidal particles; and  
4           a sufficient quantity of salt to impart an effective charge to the  
5           colloidal particles;  
6           applying a voltage to the template, thereby causing the charged colloidal  
7           particles to be deposited on the template to form a green shell; and  
8           sintering the green shell to form a solidified shell having greater mechanical  
9           integrity than the green shell.
- 10    2.     The method of claim 1, wherein the template comprises a conductive material.
- 11    3.     The method of claim 1, wherein the template comprises a conductive coating.
- 12    4.     The method of claim 3, wherein the conductive coating is a sputtered coating.
- 13    5.     The method of claim 1, wherein the slurry is nonaqueous.
- 14    6.     The method of claim 5, wherein the slurry has a dielectric breakdown voltage  
15           greater than about 50 VDC.
- 16    7.     The method of claim 5, wherein the slurry comprises a material selected from  
17           the group consisting of butanol, methanol, ethanol, and propanol.
- 18    8.     The method of claim 1, wherein the colloidal particles comprise a material  
19           selected from the group consisting of silica, glass, alumina, silicon nitride,  
20           silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum and  
21           titanium.
- 22    9.     The method of claim 1, wherein the colloidal particles have an average  
23           particle size of less than 75  $\mu\text{m}$ .
- 24    10.    The method of claim 1, wherein the colloidal particles have an average  
25           particle size of less than 40  $\mu\text{m}$ .

- 1 11. The method of claim 1, wherein the colloidal particles have an average  
2 particle size of less than 10  $\mu\text{m}$ .
- 3 12. The method of claim 1, wherein the colloidal particles have an average  
4 particle size of less than 1  $\mu\text{m}$ .
- 5 13. The method of claim 1, wherein the colloidal particles have an average  
6 particle size of less than 100 nm.
- 7 14. The method of claim 1, wherein the colloidal particles have an average  
8 particle size of less than 10 nm.
- 9 15. The method of claim 1, wherein the salt is selected from the group consisting  
10 of sodium chloride, potassium chloride, rubidium chloride, cesium chloride,  
11 zinc chloride, and potassium carbonate.
- 12 16. The method of claim 1, wherein the salt is a metal salt.
- 13 17. The method of claim 16, wherein the metal salt is a halide or a carbonate.
- 14 18. The method of claim 1, wherein the salt is an alkyl halide.
- 15 19. The method of claim 1, wherein the salt is present in a concentration of 5% by  
16 weight or less.
- 17 20. The method of claim 1, wherein the salt is present at a concentration in the  
18 slurry that is at or below its solubility limit.
- 19 21. The method of claim 1, wherein the applied voltage is about 100 volts.
- 20 22. The method of claim 21, wherein the applied voltage produces a current of  
21 about 3–5 mA.
- 22 23. The method of claim 1, wherein the green shell has a pore fraction not greater  
23 than 40% by volume.

- 1    24.    The method of claim 1, wherein the green shell has a pore fraction not greater  
2            than 30% by volume.
- 3    25.    The method of claim 1, further comprising drying the green shell prior to  
4            sintering.
- 5    26.    The method of claim 1, further comprising:  
6            after immersing the template and applying a voltage, immersing the template  
7                      in a second slurry comprising a second plurality of colloidal particles;  
8                      and  
9            applying a second voltage to the template to cause the second plurality of  
10                      colloidal particles to be deposited on the green shell to increase its  
11                      thickness.
- 12   27.    A method of producing a desired article, comprising:  
13            providing a template having a predetermined shape;  
14            depositing an investment mold on the template, wherein depositing comprises:  
15                      immersing the template in a slurry, the slurry comprising a plurality of  
16                      colloidal particles and a sufficient quantity of salt to impart an  
17                      effective charge to the colloidal particles;  
18                      applying a voltage to the template, thereby causing the charged  
19                      colloidal particles to be deposited on the template to form a  
20                      green shell; and  
21                      sintering the green shell to form the investment mold;  
22            removing the template; and  
23            casting the desired article in the investment mold.
- 24   28.    The method of claim 27, wherein the template comprises a conductive  
25            material.
- 26   29.    The method of claim 27, wherein the template comprises a conductive coating.
- 27   30.    The method of claim 29, wherein the conductive coating is a sputtered coating.

- 1     31.     The method of claim 27, wherein the slurry is nonaqueous.
- 2     32.     The method of claim 31, wherein the slurry has a dielectric breakdown voltage  
3           greater than about 50 VDC.
- 4     33.     The method of claim 31, wherein the slurry comprises a material selected from  
5           the group consisting of butanol, methanol, ethanol, and propanol.
- 6     34.     The method of claim 27, wherein the colloidal particles comprise a material  
7           selected from the group consisting of silica, glass, alumina, silicon nitride,  
8           silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum and  
9           titanium.
- 10    35.     The method of claim 27, wherein the colloidal particles have an average  
11          particle size of less than 75  $\mu\text{m}$ .
- 12    36.     The method of claim 27, wherein the colloidal particles have an average  
13          particle size of less than 40  $\mu\text{m}$ .
- 14    37.     The method of claim 27, wherein the colloidal particles have an average  
15          particle size of less than 10  $\mu\text{m}$ .
- 16    38.     The method of claim 27, wherein the colloidal particles have an average  
17          particle size of less than 1  $\mu\text{m}$ .
- 18    39.     The method of claim 27, wherein the colloidal particles have an average  
19          particle size of less than 100 nm.
- 20    40.     The method of claim 27, wherein the colloidal particles have an average  
21          particle size of less than 10 nm.
- 22    41.     The method of claim 27, wherein the salt is selected from the group consisting  
23           of sodium chloride, potassium chloride, rubidium chloride, cesium chloride,  
24           zinc chloride, and potassium carbonate.
- 25    42.     The method of claim 27, wherein the salt is a metal salt.

- 1    43.    The method of claim 42, wherein the metal salt is a halide or a carbonate.
- 2    44.    The method of claim 27, wherein the salt is an alkyl halide.
- 3    45.    The method of claim 27, wherein the salt is present in a concentration of 5%  
4        by weight or less.
- 5    46.    The method of claim 27, wherein the salt is present at a concentration in the  
6        slurry that is at or below its solubility limit.
- 7    47.    The method of claim 27, wherein the applied voltage is about 100 volts.
- 8    48.    The method of claim 47, wherein the applied voltage produces a current of  
9        about 3-5 mA.
- 10   49.    The method of claim 27, wherein the green shell has a pore fraction not  
11        greater than 40% by volume.
- 12   50.    The method of claim 27, wherein the green shell has a pore fraction not  
13        greater than 30% by volume.
- 14   51.    The method of claim 27, further comprising drying the green shell prior to  
15        sintering.
- 16   52.    The method of claim 27, further comprising:  
17        after immersing the template and applying a voltage, immersing the template  
18            in a second slurry comprising a second plurality of colloidal particles;  
19            and  
20        applying a second voltage to the template to cause the second plurality of  
21            colloidal particles to be deposited on the green shell to increase its  
22            thickness.
- 23   53.    A method of producing a desired article by investment casting, comprising:  
24        providing a master template having a predetermined shape;

- 1        using the master template to produce a transfer mold having a shape  
2                complementary to the master template, wherein the transfer mold  
3                comprises a flexible material;  
4        molding a sacrificial template in the transfer mold, the sacrificial template  
5                comprising a material that can be melted, burned, or leached;  
6        depositing an investment mold on the sacrificial template, wherein depositing  
7                comprises:  
8                immersing the template in a slurry, the slurry comprising a plurality of  
9                        colloidal particles and a sufficient quantity of salt to impart an  
10                        effective charge to the colloidal particles;  
11                applying a voltage to the template, thereby causing the charged  
12                        colloidal particles to be deposited on the template to form a  
13                        green shell; and  
14                sintering the green shell to form the investment mold;  
15        removing the sacrificial template by melting, burning, or leaching, without  
16                damaging the investment mold; and  
17        casting the desired article in the investment mold.
- 18    54.    A casting mold, comprising:  
19                a hollow shell comprising a plurality of partially or fully sintered particles and  
20                a measurable quantity of salt residue.
- 21    55.    The casting mold of claim 54, wherein the particles comprise a ceramic  
22                material.
- 23    56.    The casting mold of claim 54, wherein the partially or fully sintered particles  
24                have an average particle size of less than about 75  $\mu\text{m}$ .
- 25    57.    The casting mold of claim 54, wherein the partially or fully sintered particles  
26                have an average particle size of less than about 40  $\mu\text{m}$ .
- 27    58.    The casting mold of claim 54, wherein the partially or fully sintered particles  
28                have an average particle size of less than about 10  $\mu\text{m}$ .

- 1 59. The casting mold of claim 54, wherein the partially or fully sintered particles  
2 have an average particle size of less than about 1  $\mu\text{m}$ .
- 3 60. The casting mold of claim 54, wherein the partially or fully sintered particles  
4 have an average particle size of less than about 100 nm.
- 5 61. The casting mold of claim 54, wherein the partially or fully sintered particles  
6 have an average particle size of less than about 10 nm.
- 7 62. The casting mold of claim 54, wherein the salt residue is selected from the  
8 group consisting of sodium chloride, potassium chloride, rubidium chloride,  
9 cesium chloride, zinc chloride, and potassium carbonate.
- 10 63. A casting mold, produced by:  
11 immersing at least a first portion of a template in a first slurry, the first slurry  
12 comprising  
13 a plurality of colloidal particles; and  
14 a sufficient quantity of salt to impart an effective charge to the  
15 colloidal particles;  
16 applying a voltage to the template, thereby causing the charged colloidal  
17 particles to be deposited on the template to form a green shell about at  
18 least the first portion of the template; and  
19 sintering the green shell to form the casting mold having greater mechanical  
20 integrity than the green shell.
- 21 64. The casting mold of claim 63, wherein the colloidal particles comprise a  
22 material selected from the group consisting of silica, glass, alumina, silicon  
23 nitride, silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum  
24 and titanium.
- 25 65. The casting mold of claim 63, wherein the colloidal particles have an average  
26 particle size of less than about 75  $\mu\text{m}$ .

- 1    66.    The casting mold of claim 63, wherein the colloidal particles have an average  
2           particle size of less than about 40  $\mu\text{m}$ .
- 3    67.    The casting mold of claim 63, wherein the colloidal particles have an average  
4           particle size of less than about 10  $\mu\text{m}$ .
- 5    68.    The casting mold of claim 63, wherein the colloidal particles have an average  
6           particle size of less than about 1  $\mu\text{m}$ .
- 7    69.    The casting mold of claim 63, wherein the colloidal particles have an average  
8           particle size of less than about 100 nm.
- 9    70.    The casting mold of claim 63, wherein the colloidal particles have an average  
10          particle size of less than about 10 nm.
- 11   71.    The casting mold of claim 63, wherein the salt is selected from the group  
12          consisting of sodium chloride, potassium chloride, rubidium chloride, cesium  
13          chloride, zinc chloride, and potassium carbonate.
- 14   72.    The casting mold of claim 63, wherein the salt is a metal salt.
- 15   73.    The casting mold of claim 72, wherein the salt is a halide or a carbonate.
- 16   74.    The casting mold of claim 63, wherein the salt is an alkyl halide.
- 17   75.    The casting mold of claim 63, wherein the green shell has a pore fraction not  
18          greater than 40% by volume.
- 19   76.    The casting mold of claim 63, wherein the green shell has a pore fraction not  
20          greater than 30% by volume.
- 21   77.    The casting mold of claim 63, wherein the green shell comprises a plurality of  
22          layers of particles, and wherein adjacent layers of particles differ in size  
23          distribution or in composition.



1     78.     The casting mold of claim 63, further produced by, before sintering the green  
2             shell:  
3             immersing the template in a second slurry comprising a plurality of colloidal  
4             particles; and  
5             allowing the slurry to dry, thereby causing the colloidal particles to be  
6             deposited on a second portion of the template and the green shell to  
7             form a second green shell.